International Journal of Agricultural Science and Research (IJASR)
ISSN (P): 2250-0057; ISSN (E): 2321-0087
Vol. 7, Issue 6, Dec 2017, 325-334

EFFECT OF SOIL AND WATER CONSERVATION MEASURES ON GROUND WATER FLUCTUATIONS AND RECHARGE ON MUTUKULA WATERSHED, PRAKASAM DISTRICT

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ABSTRACT

A watershed is commonly defined as an area, in which all water drains to a common point. From a hydrological perspective, a watershed is a useful unit of operation and analysis because; it facilitates a systems approach to land and water use, in interconnected upstream and downstream areas. Watershed projects aim to maximize the quantity of water available for crops, livestock and human consumption, through on-site soil and moisture conservation, infiltration into aquifers, and safe runoff into surface ponds. Hence, the present study conducted on experimental investigations on ground water fluctuations and recharge carried out using the water level indicator, empirical equations like proposed empirical relationship, Chaturvedi formula and Chaturvedi formula. The rainfall recharge was found to be less than 5 inches. On the other hand, average rainfall recharge computed from all three equations like proposed empirical relationship (1.43), Chaturvedi formula (0.92) and Modified Chaturvedi formula (1.94) inches. Where, it was found, in Modified Chaturvedi formula and empirical relationship being quite high. Therefore, Chaturvedi formula equation can conveniently be used for better and quick assessment of natural ground water recharge, in Mutukula watershed area.

***KEYWORDS:** Watershed, Empirical Relationship, Chaturvedi Formula, Modified Chaturvedi Formula*, **NGOs, DWMA, IWDP, NWDPRA & MGNREGA**

Received: Sep 20, 2017; **Accepted:** Oct 11, 2017; **Published:** Nov 22, 2017; **Paper Id.:** IJASRDEC201745

Original Article

INTRODUCTION

Runoff is one of the most important hydrologic variables, used in most of the water resources applications. Reliable prediction of quantity and rate of runoff, from land surface into streams and rivers is difficult and time consuming, to obtain for ungauged watersheds. This information is needed, in dealing with many watershed development and management problems. Conventional models for prediction of river discharge, require considerable hydrological and meteorological data. Collection of these data is expensive, time consuming and a difficult process. Prakasam district, Andhra Pradesh is selected for this study. The district was selected because of two reasons. Firstly, in most of the areas in the district, agriculture is rain-fed and the rain fall is scarce and erratic. Secondly, it is one of the few districts, not only in Andhra Pradesh, India, but also in the country, where a number of watershed programmes have been launched in the rain-fed areas and a number of NGOs were entrusted, with the initiation and management of watershed programme. Data related to the climatic conditions like rainfall, total area, forest area, population and status of the population will be collected from the respective government

departments and various agencies. Post project data will be obtained, by carrying out the survey of people in the watershed.

The Mutukula watershed with an extent of 5100 ha, that lies in Prakasam district, in Andhra Pradesh. This area is bounded by 16^{0}10'45.4" Northern latitude and 79^{0}27'53.5" Eastern longitude, with average elevation ranging 620 m, above MSL. The watershed receives an annual rainfall of 750 mm, the minimum and maximum temperature is in the range 25^{0}C to 45^{0}C, of the study area and its location map. The Central portion of the District contains large tracts of low shrubs and Jungle, diversified with rocky hills and stony plains, which is a peculiar feature of the District.

In the light of the above discussion, it is proposed to assess the impact of watershed works, on Effect of soil and water conservation measures, on ground water fluctuations and recharge. In this connection, a research work is proposed for Mutukula watershed, Prakasam (district) in Andhra Pradesh.

MATERIALS AND METHODS

The government of India, after the formulation of new guidelines by Sri. Hanumanthaish Committee, has been allocating cores of budget, to the integrated watershed development programs, during the past two decades, on soil and water conservation programs, were successfully implemented by the district administration and, close monitoring by the various government agencies like DPAP, DRDA, IWDP, NWDPRA, MGNREGA etc was done. The project implementing agencies will have to work, as per the guidelines and should finish the budget within the stipulated time of the frame of work. Hence, it is of paramount importance, to assess the impact of various soil and water conservation works circulated in the watershed, in view of huge public amount involved in it. To fulfill the proposed objective, a base line preliminary data of water table depth, in all the wells were recorded two times in the study period i.e., pre monsoon and post monsoon. This data was procured from ground water department, Ongole, Pullalacheruvu Mandel, Prakasam District agency.

Similarly, to know the impact of ground water recharge scenario, the data of depth to ground water table is directly observed, in the same above wells of farmers, and ground water department wells, using water level indicator, (**Geotech environmental equipment)**. The aquifer of study area, majorly found to be crystalline aquifer type, the crystalline aquifer and granite-gneiss system occupies major parts of the study area. The crystalline aquifer system lacks primary porosity and the occurrence, movement of ground water in these rock types, depends on the thickness of weathered zone available and, degree of fracturing/jointing. The thickness of weathered zone varies from 3.0 to 15.0 m, soil stony/rocky type, the annual rainfall 750 mm, and second aquifer. The alluvium consisting of fine sand, gravel and kankar occur in coastal alluvium, river alluvium and windblown sands, in the area around Chirala, Vetapalem, Chinnaganjam, Nagulappalapadu, Kothapatnam, Ulvalapadu and Tanguturu, including the study area, with a thickness of 15.0 m has fresh water pockets along the coastal line. The river alluvium occurs along the course of Gundalakamma, Musi, Paleru and Manneru rivers in the district, but the quality of water is slightly brackish. The quality of water is mostly saline, as per the central ground water department, the draft found command 441 ha-m, non command 1198 ha-m and total 1639 ha-m. (Source: Ground water broacher Prakasam District, Andhra Pradesh).

The water level indicator was taken from the soil and water conservation laboratory, college of agricultural engineering, Bapatla. The instrument consists of length, 15 m. This simple water level indicator, having cable reel to bound the wire, and crank handle to release wire from cable reel, calibrated cable with insulated wire for measuring water levels in wells, weighted end having inner electrode inside, indicator buzzers or lights have two colors, one is red and another one is in green and a 9 V battery used in this. When the indicator is switched on, the red color will be turned on; when the

weighted calibrated end touches the water surface, the green color will be turned on. This simple water level indicator will activate an active buzzer, in order to make a noise, when the water reaches certain level. Because, the water sensor and the command circuit are located on the same printed circuit board indicator, together with its 9 V battery and the buzzer can be mounted in a compact case. Obviously, the sensor that is made by corrosion, on the board must not be mounted directly on iron or steel bathtubs, but with a magnet attached on the case.

The disadvantage to this type of homemade instrument is that, the line is not calibrated, which will make measurements inconvenient. But, especially for shallow water levels, it will work adequately for studies, not requiring a high degree of precision. This type of indicator will not work, if a free organic liquids like gasoline or oil is floating on top of the water in the well, because organic liquids usually are not good conductors of electricity. The same may be true for water with very low dissolved-salt content. This type of indicator may give a false reading, if the wire ends touches the water, that has condensed on the inside of the well casing, above the true water surface. If, the well is constructed with metal casing, and if the wires contact the casing, it may conduct the current and give a false reading. Finally, in using an electric cable water-level indicator, it is better to rely on the depth-to-water reading obtained, while lowering the cable rather than, that obtained while raising it.

As per the observation, wells established by ground water department were only having two in number, exactly lying in the study area, for exact impact assessment in the study area watershed, 2 wells owned by farmers in upper rich, 1 in middle rich, and 2 wells in lower rich were selected, representing the whole watershed. The details of owner and location are represented in table 1.

Table 1: Details of Farmers and Location of Wells in Study Area

Well number	Name of the former	Location of well
1	G. Gangadhara Jagannatha Rao	pullalacheruvu (chowtapalli)
2	B. Laxmaiah	Chowtapalli
3	Ch. Ravi	Chowtapalli
4	B. china venkataiah	Chowtapalli
5	L. Adam	Chowtapalli

As a part of the study, due to non availability of various input parameters, the following popularly used empirical methods like Chaturvedi formula and Kumar and Seethapathi formulas, were chosen, which exactly quantify the amount of ground water recharge in the study area. The chaturvedi formula was given by:

Chaturvedi Formula

Based on the water level fluctuations and rainfall amounts in Ganga-Yamuna doab, Chaturvedi in 1936, derived an empirical relationship to arrive at the recharge, as a function of annual precipitation.

$$R_r = 2.0\,(P - 15)^{0.4} \qquad (1)$$

Where,

R_r = net recharge due to precipitation during the year, in inches, and

P = annual precipitation, in inches.

This formula was later modified by further work at the U. P. Irrigation Research Institute,

Roorkee and the modified form of the formula is

$$R_r = 1.35\ (P - 14)^{0.5} \quad (2)$$

The Chaturvedi formula has been widely used for preliminary estimations of groundwater recharge, due to rainfall. It may be noted that there is a lower limit of the rainfall below which the Recharge due to rainfall is zero. The percentage of rainfall recharged commences from zero at P = 14 inches, increases up to 18% at P = 28 inches, and again decreases. The lower limit of rainfall in the formula may account for the soil moisture deficit, the interception losses and potential evaporation. These factors being site specific, one generalized formula may not be applicable to all the alluvial areas. Tritium tracer studies on groundwater recharge in the alluvial deposits of Indo-Gangetic plains of western U. P., Punjab, Haryana and alluvium in Gujarat state have indicated variations with respect to Chaturvedi formula.

Kumar and Seethapathi (2002)

They conducted a detailed seasonal groundwater balance Study in Upper Ganga Canal command area, for the period 1972-73 to 1983-84, to determine groundwater recharge from rainfall. It was observed that, as the rainfall increases, the quantity of recharge also increases, but the increase is not linearly proportional. The recharge coefficient (based upon the rainfall in monsoon season) was found to vary between 0.05 to 0.19, for the study area. The following empirical relationship (similar to Chaturvedi formula) was derived, by fitting the estimated values of rainfall recharge and the corresponding values of rainfall, in the monsoon season through the non-linear regression technique.

$$R_r = 0.63\ (P - 15.28)^{0.76} \quad (3)$$

Where,

R_r = Groundwater recharge from rainfall in monsoon season (inch),

P = Mean rainfall in monsoon season (inch).

The relative errors (%) in the estimation of rainfall recharge, computed from the proposed empirical relationship were compared with groundwater balance study. In almost all the years, the relative error was found to be less than 8%. On the other hand, relative errors (%) computed from Chaturvedi formula (equations 1 and 2), were found to be quite high. Therefore, equation (3) can conveniently be used, for better and quick assessment of natural groundwater recharge, in Upper Ganga Canal command area.

Amritsar Formula

Using regression analysis for certain doabs in Punjab, the Irrigation and Power Research Institute, Amritsar, developed the following formula in 1973.

$$R_r = 2.5\ (P - 16)^{0.5} \quad (4)$$

Where,

R_r and P are measured in inches.

Krishna Rao

Krishna Rao gave the following empirical relationship in 1970, to determine the groundwater recharge in limited climatological homogeneous areas.

$$R_r = K\ (P - X) \quad (5)$$

The following relation is stated to hold good for different parts of Karnataka.

R_r = 0.20 (P - 400) for areas with annual normal rainfall (P) between 400 and 600 mm

R_r = 0.25 (P - 400) for areas with P between 600 and 1000 mm

R_r = 0.35 (P - 600) for areas with P above 2000 mm

Where,

R_r and P are expressed in millimeters.

The relationships indicated above, which were tentatively proposed for specific hydro geological conditions, have to be examined and established or suitably altered for application to other areas. The individual parameters of above formulas were directly or indirectly assessed, based on the information collected from the DMA authority.

RESULTS AND DISCUSSIONS

The ground water recharge of monsoon and non-monsoon values is enlisted in Table 2. In monsoon season, highest mean rainfall was 28.3 in the year of 1983 and, lowest value was 11.3 and in non-monsoon season, highest mean rainfall was 14.8 in the year of 2008 and, lowest value was 1 inches in the year of 1984.

Table 2: Mean Rainfall Recharge of Monsoon and Non-Monsoon Seasons Year Wise

Sl. No	Years	Mean Rainfall Monsoon Season (inches)	Mean Rainfall Non-monsoon Season (inches)
1	1980	16.7	3.4
2	1981	13.4	3.3
3	1982	13.7	4.3
4	1983	28.3	2.2
5	1984	11.7	1.0
6	1985	19.9	5.8
7	1986	16.7	5.8
8	1987	18.1	10.0
9	1988	19.5	4.3
10	1989	20.3	4.3
11	1990	16.8	14.5
12	1991	20.3	8.1
13	1992	15.4	6.7
14	1993	16.2	4.7
15	1994	19.4	9.1
16	1995	22.3	4.2
17	1996	26.2	3.0
18	1997	20.9	13.3
19	1998	23.2	4.0
20	1999	16.7	1.2
21	2000	23.9	6.6
22	2001	15.4	3.2
23	2002	11.3	2.8
24	2003	15.8	2.3
25	2004	16.7	5.2
26	2005	17.8	2.1
27	2006	13.2	8.1
28	2007	17.5	1.5

Table 2: Contd.,			
29	2008	13.0	14.8
30	2009	13.7	2.4
31	2010	16.4	11.5

Determination of Natural Ground Water Recharge

Part of the rain water, that falls on the ground is infiltrated into the soil. This infiltrated water is utilized partly, in filling the soil moisture deficiency and part of it is percolated down, reaching the water table. This water reaching the water table is known as, the recharge from rainfall to the aquifer. Recharge due to rainfall depends on various hydro meteorological and topographic factors, soil characteristics and depth to water table.

The ground water balance for the study area of Mutukula watershed was carried out season-wise, for monsoon (June to October) and non-monsoon (November to May) seasons, from 1980 to 2010 (Kumar and Seethapathi, 1988). The rainfall recharge for monsoon seasons of the study period was calculated, by substituting these estimates in the ground water balance equation.

The following empirical relationship (similar to Chaturvedi formula) was derived, by fitting the estimated values of rainfall recharge and the corresponding values of rainfall in the monsoon season, through the non-linear regression technique.

$$R = 0.63 (P - 15.28)^{0.76}$$

Where,

R = Ground water recharge from rainfall in monsoon season (inch);

P = Mean rainfall in monsoon season (inch).

Based on the empirical equation (3) the recharge from the mean rainfall was observed from the monsoon and non-monsoon seasons are enlisted in the Table 3.

Table 3: Recharge from the Monsoon and Non Monsoon Seasons with Proposed Relationship

Sl. No	Years	Mean Monsoon Rainfall (P) (Inches)	Rainfall Recharge Proposed Relationship $R=0.63(P-15.28)^{0.76}$ (Inches)	Mean Non-Monsoon Rainfall (P) (Inches)	Rainfall Recharge Proposed Relationship $R=0.63(P-15.28)^{0.76}$ (Inches)
1	1980	16.7	0.940	3.39	0
2	1981	13.4	0.000	3.25	0
3	1982	13.7	0.000	4.34	0
4	1983	28.3	4.947	2.16	0
5	1984	11.7	0.000	1.00	0
6	1985	19.9	2.267	5.83	0
7	1986	16.7	0.921	5.81	0
8	1987	18.1	1.527	9.98	0
9	1988	19.5	2.119	4.34	0
10	1989	20.3	2.403	4.26	0
11	1990	16.8	0.948	14.46	0
12	1991	20.3	2.397	8.10	0
13	1992	15.4	0.162	6.74	0

Table 3: Contd.,					
14	1993	16.2	0.650	4.69	0
15	1994	19.4	2.064	9.07	0
16	1995	22.3	3.085	4.19	0
17	1996	26.2	4.324	3.04	0
18	1997	20.9	2.598	13.30	0
19	1998	23.2	3.406	4.04	0
20	1999	16.7	0.925	1.16	0
21	2000	23.9	3.631	6.57	0
22	2001	15.4	0.149	3.17	0
23	2002	11.3	0.000	2.79	0
24	2003	15.8	0.455	2.33	0
25	2004	16.7	0.902	5.24	0
26	2005	17.8	1.431	2.11	0
27	2006	13.2	0.000	8.08	0
28	2007	17.5	1.303	1.46	0
29	2008	13.0	0.000	14.80	0
30	2009	13.7	0.000	2.42	0
31	2010	16.4	0.784	11.48	0

The above proposed relationship indicates that, recharge to ground water commences at P = 15.28 inches. Therefore, it gives no recharge for the years 1981,1982,1984,2002,2006,2008,2009, and highest recharge from rainfall 4.947 in the year of 1983, for monsoon season. For non-monsoon season, recharge to ground water commences at P = 15.28 inches, but the rainfall values are less than the P values that, it indicates the 0 recharge in all the years.

Determination of Ground Water Recharge with Chaturvedi Formula

The Chaturvedi Formula was discussed in the previous chapter then the rainfall recharge was find out with help of this equation was enlisted in Table 4.

Table 4: Recharge from the Monsoon and Non Monsoon Seasons with Chaturvedi Formula

Sl. No	Years	Mean monsoon Rainfall (P) (inches)	Rainfall Recharge Chaturvedi Formula $R=2.0(P-15)^{0.4}$ (inches)	Mean Non-monsoon Rainfall (P) (inches)	Rainfall Recharge Chaturvedi Formula $R=2.0(P-15)^{0.4}$ (inches)
1	1980	16.7	0.976	3.39	0
2	1981	13.4	0.000	3.25	0
3	1982	13.7	0.000	4.34	0
4	1983	28.3	1.896	2.16	0
5	1984	11.7	0.000	1.00	0
6	1985	19.9	1.387	5.83	0
7	1986	16.7	0.968	5.81	0
8	1987	18.1	1.185	9.98	0
9	1988	19.5	1.350	4.34	0
10	1989	20.3	1.420	4.26	0
11	1990	16.8	0.979	14.46	0
12	1991	20.3	1.419	8.10	0
13	1992	15.4	0.483	6.74	0
14	1993	16.2	0.842	4.69	0
15	1994	19.4	1.336	9.07	0
16	1995	22.3	1.569	4.19	0
17	1996	26.2	1.796	3.04	0

Table 4: Contd.,					
18	1997	20.9	1.465	13.30	0
19	1998	23.2	1.633	4.04	0
20	1999	16.7	0.969	1.16	0
21	2000	23.9	1.675	6.57	0
22	2001	15.4	0.467	3.17	0
23	2002	11.3	0.000	2.79	0
24	2003	15.8	0.730	2.33	0
25	2004	16.7	0.959	5.24	0
26	2005	17.8	1.154	2.11	0
27	2006	13.2	0.000	8.08	0
28	2007	17.5	1.112	1.46	0
29	2008	13.0	0.000	14.80	0
30	2009	13.7	0.000	2.42	0
31	2010	16.4	0.907	11.48	0

The above Chaturvedi Formula indicates that, recharge to ground water commences at P = 15 inches. Therefore, it gives 0 recharge for the years 1981,1982,1984,2002,2006,2008,2009, and highest recharge from rainfall 1.896 in the year of 1983, for monsoon season. For non-monsoon season, recharge to ground water commences at P = 15 inches, but the rainfall values are less than the P values, that it indicates the 0 recharge in all the years.

Determination of Ground Water Recharge with Modified Chaturvedi Formula

The Modified Chaturvedi Formula also discussed in the previously, then the rainfall recharge was found out with the help of this equation in Table 5.

Table 5: Recharge from the Monsoon and Non Monsoon Seasons with Modified Chaturvedi Formula

Sl. No	Years	Mean monsoon Rainfall (P) (inches)	Rainfall Recharge Modified Chaturvedi Formula $R=1.35(P-14)^{0.5}$ (inches)	Mean Non-monsoon Rainfall (P) (inches)	Rainfall Recharge Modified Chaturvedi Formula $R=1.35(P-14)^{0.5}$ (inches)
1	1980	16.7	1.925	3.39	0
2	1981	13.4	0.000	3.25	0
3	1982	13.7	0.000	4.34	0
4	1983	28.3	4.392	2.16	0
5	1984	11.7	0.000	1.00	0
6	1985	19.9	2.832	5.83	0
7	1986	16.7	1.911	5.81	0
8	1987	18.1	2.339	9.98	0
9	1988	19.5	2.736	4.34	0
10	1989	20.3	2.919	4.26	0
11	1990	16.8	1.930	14.46	0.791
12	1991	20.3	2.915	8.10	0
13	1992	15.4	1.387	6.74	0
14	1993	16.2	1.716	4.69	0
15	1994	19.4	2.699	9.07	0
16	1995	22.3	3.341	4.19	0
17	1996	26.2	4.055	3.04	0
18	1997	20.9	3.042	13.30	0
19	1998	23.2	3.532	4.04	0
20	1999	16.7	1.914	1.16	0
21	2000	23.9	3.663	6.57	0

Table 5: Contd.,					
22	2001	15.4	1.379	3.17	0
23	2002	11.3	0.000	2.79	0
24	2003	15.8	1.577	2.33	0
25	2004	16.7	1.897	5.24	0
26	2005	17.8	2.272	2.11	0
27	2006	13.2	0.000	8.08	0
28	2007	17.5	2.182	1.46	0
29	2008	13.0	0.000	14.80	1.041
30	2009	13.7	0.000	2.42	0
31	2010	16.4	1.812	11.48	0

The above Modified Chaturvedi Formula indicates that, recharge to ground water commences at P = 14 inches. Therefore, it gives 0 recharge for the years 1981,1982,1984,2002,2006,2008,2009, and highest recharge from rainfall 4.392 in the year of 1983, for monsoon season. For non-monsoon season, recharge to ground water commences at P = 14 inches, but the rainfall recharge is less than the P values, that it indicates the 0 recharge in all the years, except in the years of 1990 and 2008; in these years rainfall recharge was 0.791 and 1.041 because, in those years P value was higher than the equation value.

CONCLUSIONS

The present study concluded that, the estimation of rainfall recharge from the proposed empirical relationship, as in almost all the years, the rainfall recharge was found to be less than 5 inches. On the other hand, average rainfall recharge, computed from all three equations like proposed empirical relationship (1.43), Chaturvedi formula (0.92) and Modified Chaturvedi formula (1.94) inches, which found using Modified Chaturvedi formula and empirical relationship was being quite high. Therefore, Chaturvedi formula equation can conveniently be used, for better and quick assessment of natural ground water recharge, in Mutukula watershed area.

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